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16. ABSTRACT

A set of three atmospheric tracer experiments was conducted in the Brush Creek Valley of western Colorado in the summer of 1982 as part of the U.S. Environmental Protection Agency Green River Ambient Model Assessment (GRAMA) program in conjunction with the U.S. Department of Energy's Atmospheric Studies in Complex Terrain (ASCOT) research program. Experiments were designed to determine how nighttime tracer concentrations on the valley floor and sidewalls arising from an elevated point source would change following sunrise during the temperature inversion breakup period.

Many physical processes were observed in the tracer and meteorological experiments, including nocturnal down-valley plume transport and diffusion, post-sunrise CBL growth, fumigation of the elevated plume, upslope flow development within the CBL, subsidence over the valley center, and high post-sunrise concentration on the sidewall.

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1. INTRODUCTION

A set of three atmospheric tracer experiments was conducted in the Brush Creek Valley of western Colorado in the summer of 1982 in conjunction with the U.S. Department of Energy's Atmospheric Studies in Complex Terrain (ASCOT) research program. Experiments were designed to determine how nighttime tracer concentrations on the valley floor and sidewalls arising from an elevated point source would change following sunrise during the temperature inversion breakup period. This information will be used to evaluate a valley atmospheric transport and diffusion model called VALMET, developed for the Environmental Protection Agency at DOE's Pacific Northwest Laboratory (Whiteman and Allwine, 1983a, 1983b). VALMET was developed on the basis of previous meteorological experiments in other valleys (Whiteman, 1982). Basic meteorological data, but no tracer data, were collected during these earlier experiments. VALMET predicts that concentrations will increase following sunrise as convective boundary layers (CBLs) grow upwards into the elevated nocturnal plume from the valley floor and sidewalls, thus fumigating valley surfaces. Pollutants will be removed from the valley in upslope flows that develop in the CBLs over the sidewalls. The experiments discussed here provide the first tracer data to evaluate VALMET's parameterization of these physical mechanisms.

2. EXPERIMENTAL DESIGN

Experiments were designed to evaluate parameterizations of individual physical processes included in the model. For this purpose, it was necessary to generate a continuous elevated plume in the valley on undisturbed clear weather nights and to observe the behavior of the plume following sunrise. In order to evaluate the model, concentrations were determined on the valley floor and sidewalls, vertical profiles were made through the elevated plume, time-varying concentrations were observed on one sidewall during the fumigation period, and supporting meteorological measurements were collected to investigate CBL growth and the development of upslope flows.

2.1 Topography

The Brush Creek Valley is a 650-m-deep, narrow, NW-SE-oriented, near-linear valley of 25 km length having no major tributaries. Brush Creek drains the Roan Plateau, is a main tributary to Roan Creek, and is located approximately 50-60 km NNE of Grand Junction, Colorado.

2.2 Tracer Release

In the experiments, elevated continuous releases of sulfur hexafluoride were made from a dual tethered balloon release system (Whiteman and Glover, 1983) above the center of the valley floor at the PNL site (Figure 1), approximately 10 km up the valley from its confluence with the Roan Valley. Releases were made on the clear or partly cloudy mornings of July 31, August 4, and August 6, 1982. Release data are shown below in Table 1.

Table 1.

SF_6 Release Data

Date	Release Period (MST)	Release Duration (h)	Release Rate (kg/h)	Release Height (m)
7-31-82	0458-0757	2.98	2.94	102
8-04-82	0428-0806	3.63	9.03	105
8-06-82	0410-0946	5.60	7.61	112

*On assignment from National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

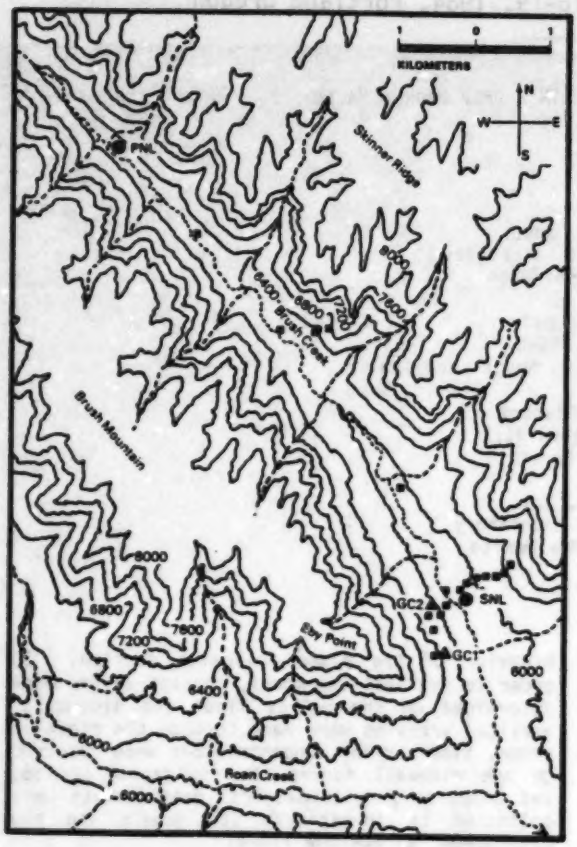

Fig. 1. Location of SF_6 sampling systems. Squares indicate the locations of the bag samplers. Triangles indicate the locations of the manually operated gas chromatographs and solid circles indicate the locations of tethered balloon sounding systems referenced in this paper. The elevated tracer release occurred at the PNL site.

2.3 Measurement Equipment

Sulfur hexafluoride concentrations were detected down-valley from the release point using an array of 18 radio-controlled bag samplers, a balloon-borne vertical SF_6 profiling system, two portable gas chromatographs located on one sidewall, and a continuous real time SF_6 monitor operated onboard a Cessna 411 research aircraft. The vertical SF_6 profiler has been previously described by Gay (1982). Observations made with the aircraft are discussed by Orgill et al. (1984).

3. RESULTS

Results of the three experiments were similar, so that, for the purposes of this paper, data from the three experiments will be used interchangeably to illustrate the physics of the phenomena.

3.1 Meteorological Observations

Hourly wind and temperature profiles were available on July 29 and 31 on the west sidewall and at up to 6 other locations within the valley as part of the ASCOT experiment. No profiles were available on the east sidewall. On August 4 and 6, observations were available at the PNL and SNL sites. During the experiments, nocturnal down-valley winds in Brush Creek Valley followed a "jet" profile with winds of 5-8 m/s at about the 100 m level (i.e., near the tracer release height), decaying to near-zero velocities at ridgetop level and at the ground. Winds blew nearly parallel to the valley axis. Reversal of the winds (to up-valley) occurred at about 0730 MST, when winds changed direction rather suddenly through the valley depth. Nocturnal temperature profiles were characterized by a 10 to 14 °K potential temperature inversion in the lowest 250-300 m of the valley with an isothermal layer above. After sunrise, growing CBLs were observed over the valley floor and the west sidewall. These layers were characterized by a shallow superadiabatic layer adjacent to the ground, surmounted by a rapidly growing, well mixed, constant potential temperature layer. Upslope winds developed within the sidewall CBL. Observations at GC2 showed that upslope winds developed shortly after the site was illuminated. A descent of the top of the isothermal stability layer over the valley center after sunrise was a feature of the inversion breakup at most tethered balloon atmospheric sounding stations in the valley. This feature has been observed in other valleys (Whiteman, 1982).

3.2 Tracer Observations

The experimental results are illustrated by 3 figures. The first figure (Fig. 2) shows SF_6 concentration as a function of time for the three experiments at gas chromatograph site GC1, located on the west sidewall approximately 8 km down-valley from the tracer release site. For reference, astronomical sunrise occurred at 0504 MST and the upper west sidewall of the valley was illuminated at 0530 MST. The highest bag sampling site on the west sidewall received sunlight at 0606 MST, and the valley floor first received sunlight at 0643 MST. The figure illustrates the rapid increase in concentrations on the west sidewall following sunrise. High concentrations decreased after 0700 MST. The nocturnal down-valley winds in the valley reversed to up-valley at 0730 MST. Concentrations decreased to near-zero by 0930 MST.

The second figure (Fig. 3) shows the results of a series of five vertical profiles through the tracer plume taken from the center of the valley floor at the SNL site. The plume was released 7.7 km up the valley from this site at an elevation 245 m higher than the SNL site. The plume was transported primarily in the lowest 300 m of the valley. Post-sunrise vertical concentration profiles are representative of fumigation, i.e. a well-mixed boundary layer grows upwards into the remnants of the nocturnal plume following sunrise. The third figure (Fig. 4) presents a series of cross section analyses of the plume concentrations at different times during the experimental period of August 4. The valley cross section is drawn through the SNL site. Data in the figure are a composite of available data. Surface data are primarily from bag samples obtained over the

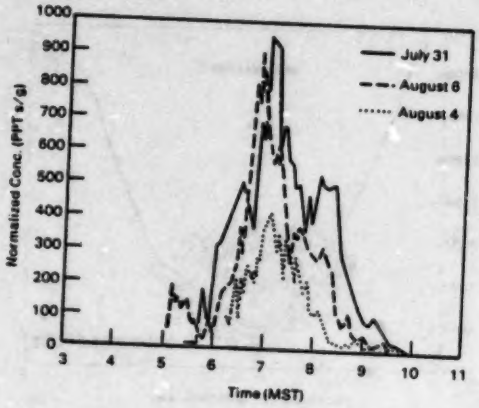

Fig. 2. SF_6 concentration (ppt) versus time, Site GC1, 1982.

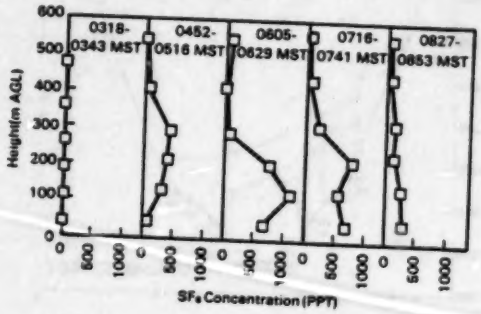

Fig. 3. Vertical profiles of normalized SF_6 concentration (ppt s/g), August 6, 1982.

time period indicated. Time series data from the manually operated gas chromatographs GC1 and GC2 were also integrated over the period indicated. Vertical concentration profiles above the valley center were taken using six syringes which were filled sequentially from a continuously ascending tethered balloon during the time period indicated at the top of the individual profiles. Instantaneous SF_6 concentration data obtained in the vicinity of the valley cross section by aircraft are indicated by plus (+) symbols.

The nocturnal tracer plume (Fig. 4a) was carried down the valley to the cross section, traveling adjacent to the east sidewall in the lowest 200 or 300 m of the valley. The plume centerline concentration of 900-1000 ppt on the cross section can be approximated with a standard Gaussian plume model, using an E stability. As sunlight progressed down the west sidewall (Fig. 4b-4e) a cross valley flow developed, advecting the tracer plume toward the sunny sidewall. High concentrations occurred on the west sidewall as the nocturnal plume was entrained into the growing CBL, fumigating the surface. Upslope flows in the growing CBL carried the tracer further up the sidewall, increasing concentrations in the upper regions of the valley. After 0730 MST the wind reversal (to up-valley) was an additional factor which caused a rapid diminution in concentrations within the lower half of the valley.

4. CONCLUSIONS

Many of the physical processes parameterized in the initial VALMET model were observed in the tracer and meteorological experiments, including nocturnal down-valley plume transport and diffusion, post-sunrise CBL growth, fumigation of the elevated plume, upslope flow development within the CBL, subsidence over the valley center, and high post-sunrise concentrations on the sidewall.

The strong asymmetry of the observed plume breakup due to cross valley advection caused by unequal insolation on the two sidewalls of the narrow NW-SE-oriented valley is an important feature that has not yet been incorporated into the VALMET model. This feature has strong implications for post-sunrise air pollution dispersion in valleys, and little experience is available to determine how strongly this depends on valley orientation and width.

Future work should be focused on modification and quantitative evaluation of VALMET, based on a thorough evaluation of the tracer data and supplementary meteorological data from the 1982 and planned 1984 DOE ASCOT/EPA experiments.

5. ACKNOWLEDGMENTS

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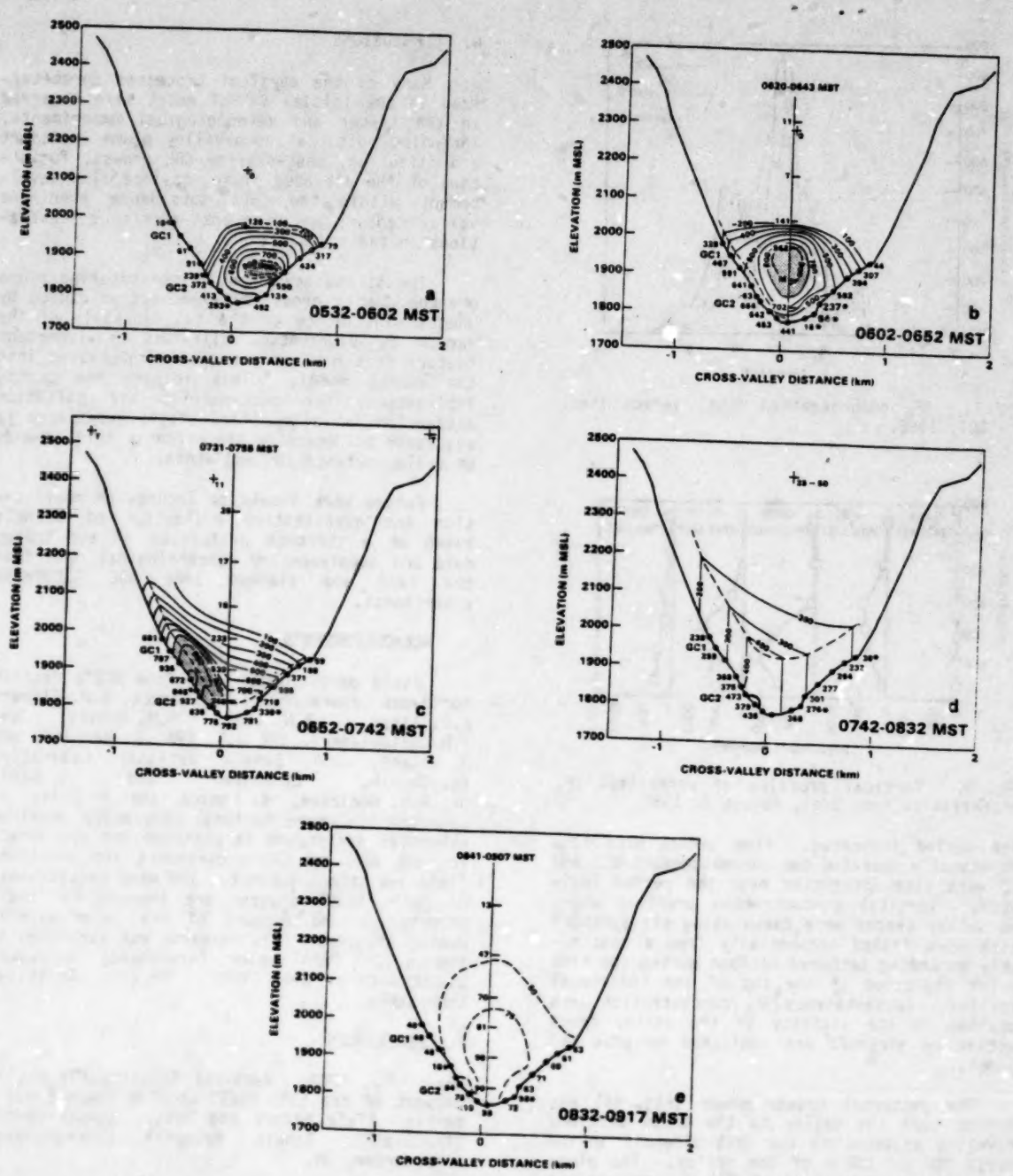

Fig. 4. Valley cross section analysis of SF_6 concentration (ppt), August 4, 1982. See text. Valley cross section is from SW to NE (left to right). Surface concentration values marked with an asterisk are suspect due to the low volume sample collected. The dashed line in the figure represents CBL height as estimated from hourly atmospheric soundings at the SNL site, and from tethered balloon observations taken on the west sidewall on July 31, 1982.

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